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Impact of climate and land use change on ecosystem services: A case study of Samutsakorn province, Thailand

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ABSTRACT

The capacity of delivering ecosystem services essential to social well- being is impeded by climate and land use change, causing a significant alteration in the quality of functions and services of many ecosystems. This paper focuses on how to project future services of coastal ecosystem in Samutsakorn province, Thailand. The 2050 climate layers are projected by using WorldClim database at 30 s resolution. Projection of land use change analysis in 2050 using a spatial allocation model is simulated by two scenarios; business as usual and sustainability driven. Result revealed that an increase in sea level, temperature and precipitation, with an associated decrease in forest cover will ultimately degrade the function and service of coastal ecosystem and impede community resilience. There is thus an urgent need on scaling up and restoring mangrove ecosystems and effective coastal adaptation to climate change which heavily depends on engagement of stakeholders at the early stage.

1. Introduction

Climate change becomes one of the biggest threats to coastal and marine ecosystems by impeding its services as source of food, natural barrier for coastal protection and local livelihood. Anthropogenic induced climate change is accelerating in unexpected rate that most ecosystem never experience before, posing a risk to the continued existence and healthy functioning of coastal ecosystem (Epanchin-Niell et al., 2017; Kingsford and Watson, 2011). Provisioning services to living organisms is an important role of ecosystem; supporting service, regulating services, provisioning services and cultural services (Luisetti et al., 2011). Ecosystem services provides a potentially valuable framework for environmental assessment, it requires a pragmatic, context specific consideration of how ecosystem services can help to address common problem in current environmental assessment (Baker et al., 2013).

Both climate change and human activities contribute to the decline of ecosystem services (Wang et al., 2016). Land use change affects the provision of ecosystem services and is accelerated by resources scarcity and impact of climate change (Bormann et al., 2012). Ecohydrologic risk criteria for land use impact on water quality and quantity in the Riva Creek watershed, Turkey have been developed by Pamukcu et al. (2016) to evaluate hydrologic risk prone area. The inclusion of ecosystem services in planning processes and clarifies the linkage between ecosystem services and social impacts result in inherent connectivity between social demands and provision of ecosystem services (Karrasch et al., 2014). Understanding the changing trends in ecosystem services in associated with its drivers both physical and socioeconomic drivers are fundamental step in informing decision makers for the development of comprehensive management of ecosystem services (Hao et al., 2017).

Projections of future SLR vary across studies, with global averages ranging between roughly 0.3–1.8 m by 2100 (Melillo et al., 2014). In recent publish of scientific literatures, sea level rise is one of the major impact on coastal areas and mangroves is the most affected ecosystem in tropics (Sierra-Correa and Cantera Kintz, 2015). Value of coastal and marine resources could be estimated in term of economic valuation (Torres and Hanley, 2017). The value of mangrove forest services is estimated at about US $200,000 to US $900,000 (Wells et al., 2006). Many services provided by mangrove are important for coastal livelihood, including coastal protection, marine habitat, water purification and tourist attraction. Successful mangrove management requires understanding of its physical characteristics to better determine their contribution to coastal protection (Horstman et al., 2013).

A long coastline of Thailand makes a country more vulnerable to climate change. Mangrove forests in Thailand have been mainly devastated by converting to shrimp farm, salt ponds and settlement side. Samutsakorn is one of the provinces of central Thailand which located 30 km from Bangkok. Total area occupied by the province is about 866 km^2. Samutsakorn is one of the places for fishing port and the biggest producer of brine salt in Thailand. The province is a location of downstream of the Ta Chin River basin where the Ta Chin River flows through Samutsakorn province and drains to Gulf of Thailand. Land use

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of the province are dominated by agriculture and urban area. The province's Gross Domestic Products are driven by industry (84.6%), followed by agriculture (9.7%) and commerce (5.7%). There was a gradual decrease in the area of agricultural land and increase in urban land in Samutsakorn as shown in land use map of 2006 and 2013. The coastal mangrove forest of Samutsakorn plays an important role in protecting land and surroundings communities from extreme weathers such as storms and erosions. It is productive ecosystem services that provide food sources for marine organisms and local communities while also offering significant nursery habitat for mangrove inhabitants. In the past 50 years, Mangrove forests in Thailand have been considerably destroyed by humans in order to convert to different land use types; aquaculture, industry estate and salt pan.

This study aims at exploring the climate and land use projection of for Samutsakorn province in 2050 to assess the likely impact on mangrove forest. Samutsakorn was chosen as a case study because a province has extensive industrial activities in relation to fishery and aquaculture. Many physical and socio-economic drivers e.g. urban sprawl, fishery activities and labor migration are the main causes of land use change and environmental degradation.

2. Methods

2.1. Climate projection

The climate projection for 2050s (2040–2060) is prepared by using WorldClim database. WordClim is a set of global gridded climate data with different spatial resolutions expressed as minutes or seconds of a degree of longitude or latitude. The resolution of 30 s (about 1 km^2) and Representative Concentration Pathway 4.5 (RCP 4.5) has been selected for projecting four climate parameters; maximum temperature, minimum temperature, mean temperature and precipitation in Samutsakorn province. Sea level rise projection has also been derived by ensemble of four models; NorESM1-M, GISS-E2-R, GISS-E2-R-CC and MIROC-ESM.

2.2. Land use projection

In order to determine land use assumptions and growth projections for Samutsakorn province, secondary data analysis is conducted by reviewing provincial reports, policy and strategic plans to define driving forces behind future land use changes. Three scenarios have been constructed by extracting useful information derived from secondary data, literatures and stakeholders i.e. economic, business as usual and sustainability driven.

Land use has been divided into five classes; agriculture, forest, miscellaneous, urban and water. The physical and socio-economic drivers comprise distance to road, distance to river, population density, flood prone area and land suitability for rice. The conversion resistance is one of the specific settings to determine the temporal dynamics of the simulation (Verburg et al., 2015). Land use type with high capital investment cannot be easily converted to other uses such as urban and natural water sources. Therefore, dimensionless factors have been assigned to each type of land use, ranging from 0 (easily conversion) to 1 (irreversible change). Land use conversion resistance for two scenarios is shown in Table 1.

The productive capacity of one cell of a land use type for a specific land use service is defined by services matrix. Urban and mangrove forest land (km^2) have been defined as three land use services. Conversion from one land use type to another land use type needs to be considered by the model where 0 equals "no conversion allowed" and 1 equals "conversion allowance". Future land use demands are estimated by using yearly percentage of increase. The business as usual and sustainability driven scenarios for percent increase in urban and mangrove land are 4, 2, 1% and 0.1, 1, 4% respectively. The simulation duration for land use projection is 47 years long (2050) as same duration of climate projection.

Table 1
Land use conversion resistance for business as usual and sustainability driven scenarios.

Land use	Business as usual	Sustainability
Agriculture	0.50	0.70
Forest	0.50	1
Miscellaneous	0.20	0.10
Urban	1	1
Water	1	1

2.3. Ecosystem services assessment

Simple matrix table has been created to assess three ecosystem services of mangrove forest; provisioning, regulating and supporting services in 2050 comparing to baseline climate (1960–1990). Mangrove forest requires stable sea levels for long term survival. Higher precipitation can reduce nutrient and salinity control of mangrove forest while higher temperature can also have a negative impact on phenological pattern, productivity and species composition. The increase in mangrove forest area will provide a range of benefits to ecosystem services in term of provisioning resources e.g. wood materials, fuel and medicine; providing habitat to marine species; protecting coastal erosion from waves and storms.

3. Results

3.1. Climate projections

Maximum, minimum and mean monthly temperatures, including mean annual precipitation for baseline year (1960–1990) is depicted in Fig. 1.

Climate change projection of Samutsakorn province in 2050 is shown in Fig. 2. Temperature tends to be higher both maximum, minimum and mean monthly temperature when comparing with baseline year in Fig. 1.

In comparison to baseline year (1960–1990), precipitation tends to be steady and/or decrease from 1300 mm to 1270 mm. There are significant increases in monthly temperature by about 2 °C in Samutsakorn. The projected mean temperature change in the eastern side of Samutsakorn is higher than those appeared in the western side.

Sea level rise scenario in 2050 in Gulf of Thailand is generated by four models ensemble as shown in Fig. 3. Results reveal a general trend of sea level increasing by 27 cm for mid scenario in 2050.

As mangroves are sensitive to inundation characteristics e.g. duration and frequency, it would likely possible that the increase in sea level in the Gulf of Thailand can potentially deteriorate mangrove area along the coastline of the province. When considering precipitation in 2050, there might be possible that extreme water related events such as drought will accelerate the rate of sea water intrusion by the shortage of freshwater to push sea water back away from aquifer. Aquaculture and paddy rice are also expected to be destroyed by the effect of sea water intrusion.

3.2. Land use projection

Two scenarios of land use projection; Business as usual (BAU) and Sustainability Driven (SD) is constructed by reviewing of related literatures and informal talking to coastal community. BAU tends to be driven by the development of industries along with urban expansion, while shrinking in miscellaneous has to be expected to change to agriculture. Fig. 4 reveal a comparison between land use map in 2013 and the projected land use in 2050 under BAU scenario.

In contrast with BAU, SD scenario encourages a conservation of

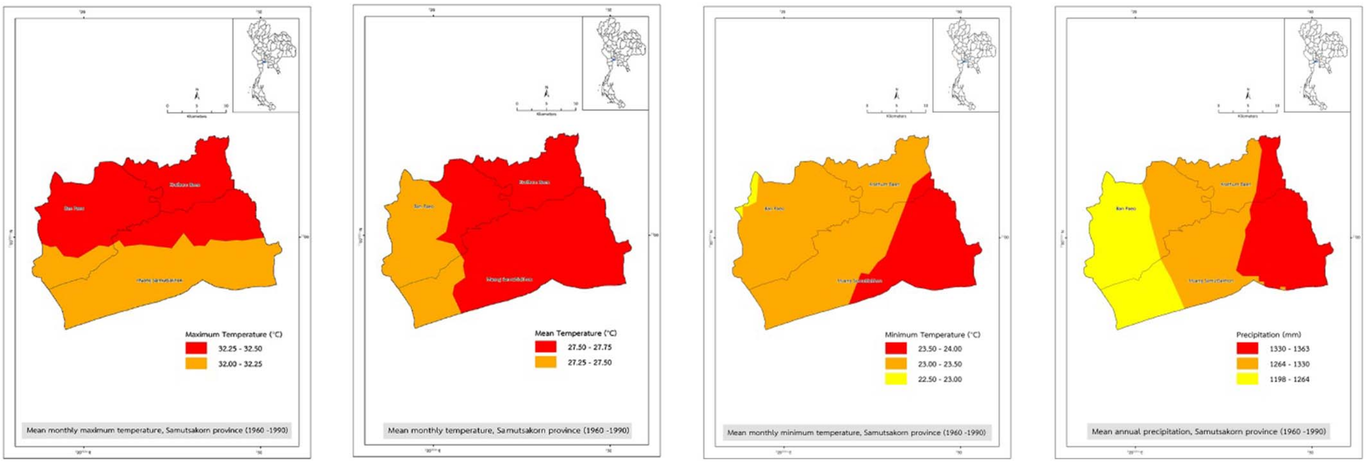

Fig. 1. Baseline climate parameters for maximum, minimum, mean monthly temperatures and mean annual precipitation.

existing mangrove areas and promotes regrowth of mangrove to increase capacity of coastal ecosystem services as shown in Fig. 5.

3.3. Ecosystem services assessment

A simplified ecosystem service value matrix of mangrove forest has been used to evaluate impact of projected climate and land use change on three major categories of ecosystem services; provisioning, regulating and supporting services. The increase of ecosystem services of mangrove forest is represented by plus sign (+) while minus sign (−) represents a change that tends to degrade the function of mangrove forest. If such a change is no effect on ecosystem services, it is represented by "x" symbol. A simplified ecosystem services of mangrove forest is shown in Table 2.

From Table 2, the increase in sea level rise shows negative affect on ecosystem services of mangrove forest. An increase in mean monthly temperature and little decrease in amount of precipitation have no influence on mangrove services due to not exceeding photosynthesis capability of mangrove species at 28–32 °C (Ball and Sobrado, 2002). Considering the impact of land use change in 2050 under two different scenarios, the trajectory on SD scenario appears to be even less negative impact on ecosystem services of mangrove forest than BAU scenario due to the net increase in mangrove forest cover. It should be noted that the increase in mangrove forest area will support provisioning, regulating and habitat of mangrove forest.

4. Discussion

Climate projection of monthly temperature (average, maximum and minimum) in Samutsakorn reveals an increasing trend under medium stabilize scenarios leading to intermediate outcomes (RCP 4.5). Amount of precipitation is projected to be little decrease or no net change while sea level rise is projected to rise by 2050, resulting in a major threat to coastal livelihood e.g. sea water intrusion, coastal floods and agriculture disastrous. Either the increase in temperature or sea level rise will contribute to increase in evaporation, change in inundation duration and frequency and degradation of suitable salinity level. It should be noted that an increase of temperature is not exceeding photosynthesis capability of mangrove forest. Socioeconomic pathways in term of possible land use change have implication on climate change projection. Urban expansion is associated with business as usual (BAU) land use scenario. Sustainability driven land use scenario will be highly beneficial for ecosystem services by increasing mangrove forest cover. It would be very important to plan for coastal adaptation due to dual effects of climate and land use change. The increase in sea level rise and precipitation in associated with business as usual land use will ultimately results in a decline of ecosystem services of mangrove forest.

Planning for provincial strategies both in short term and long term can capable of conserving ecosystem and increase resilience of coastal communities from climate and land use change perspectives. Mangrove reforest is one of common strategies that are currently promoted by government and business organizations as a social responsibility campaign. However, long term monitoring of mangrove reforest is required

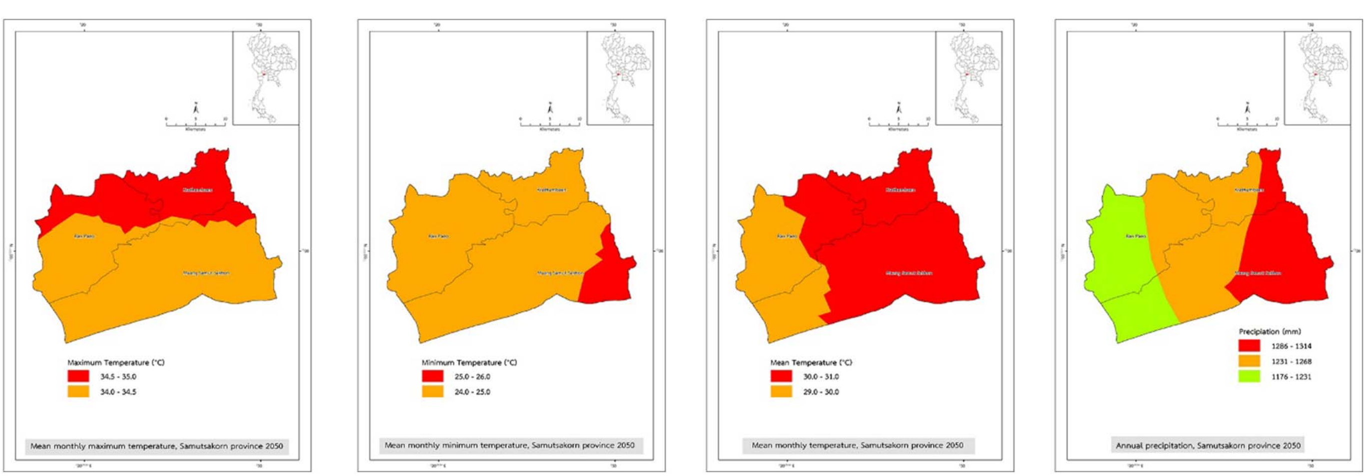

Fig. 2. Projected changes in maximum, minimum, mean monthly temperatures and mean annual precipitation in 2050.

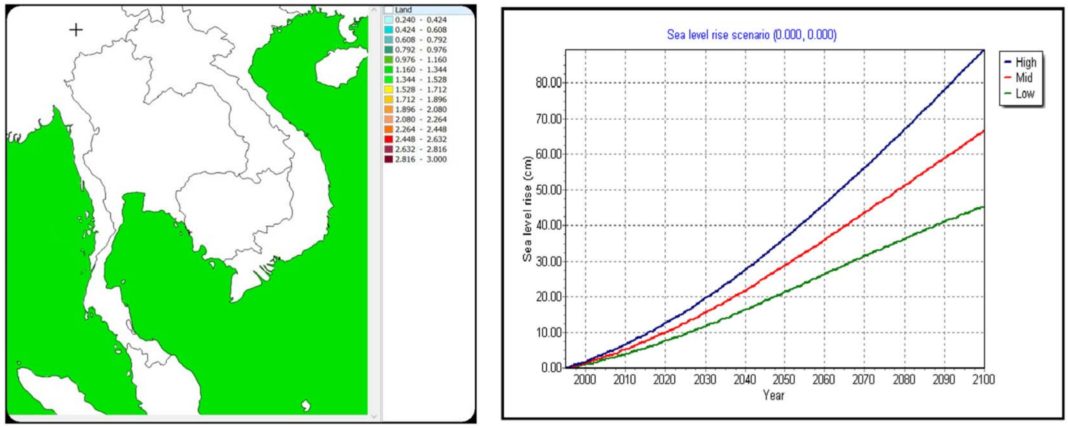

Fig. 3. Map of sea level rise in the Gulf of Thailand (left) and trend of sea level rise during 2000–2100 (right).

for increasing survival rate of regrowth of mangroves. An implementation of coastal protection strategies is necessary for both mangrove and coastal community. An installation of bamboo wall for protecting coastal erosion and increasing survival of regrowth mangrove is currently applied in Samutsakorn province. It would be useful if other protection strategies such as redefine of marine aquaculture zone and coastal development setbacks are taken into consideration in long term plan and policies. Capacity building of coastal communities will allow them to gain necessary knowledge of climate change and to increase their awareness on how to adapt to climate change.

5. Conclusion

Mangrove forest plays multiple roles as habitat for numerous species, food resources and sustains well-being of coastal community in tropic region. Downscaled climate projection of HadGM-ES at RCP 4.5 in 2050 shows a sign of both increasing in temperature and little decrease in precipitation. Trend in sea level is projected to rise under middle sensitivity, reaching 27 cm. Sea level rise is a potential climate change threat to forest degradation and physical effect e.g. respiration and forest productivity while reduced precipitation can affect sediment input groundwater and salinity. Land use change under BAU scenario indicates the significant urban expansion and shrinking of mangrove forest area. There is reverse trend in SD scenario which shows the increase in mangrove area. Integration of climate and land use change assessment on provisioning, regulating and habitat services of mangrove forest reveals significant threat to mangrove forest and its services under both BAU and SD land use scenarios. A trajectory on SD scenario appears to be even less negative impact on ecosystem services of mangrove forest than BAU scenario. Analysis results suggest the recent trend towards urgent need on scaling up and restoring mangrove forest and promoting effective coastal adaptation to climate change which considerably depends on engagement of stakeholders at the early stage. However, uncertainty in climate and land use change projection, including short term strategic planning for provincial level (5 years) is a major obstacle to coastal adaptation. In response to uncertainty issues, It would be more proactive approach to develop adaptation planning for mangrove forest based on considering of climate and land use change scenarios with more systematic assessment of ecosystem services of mangrove forest. Government should encourage an

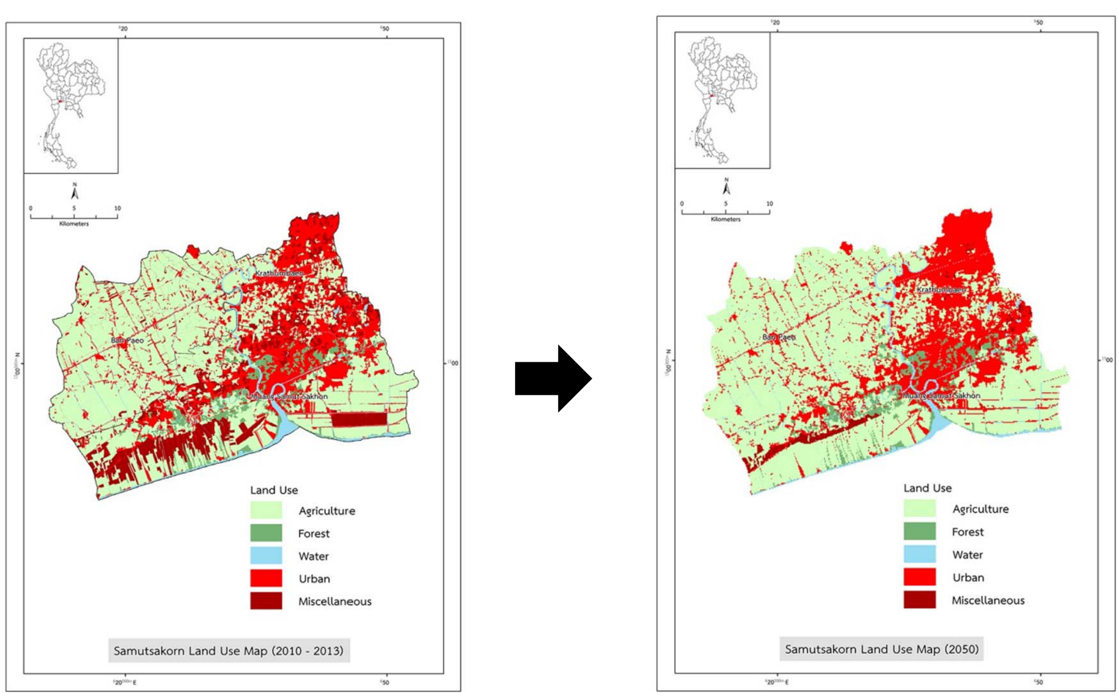

Fig. 4. A comparison between 2013 land use and 2050 modeled land use under BAU scenario.

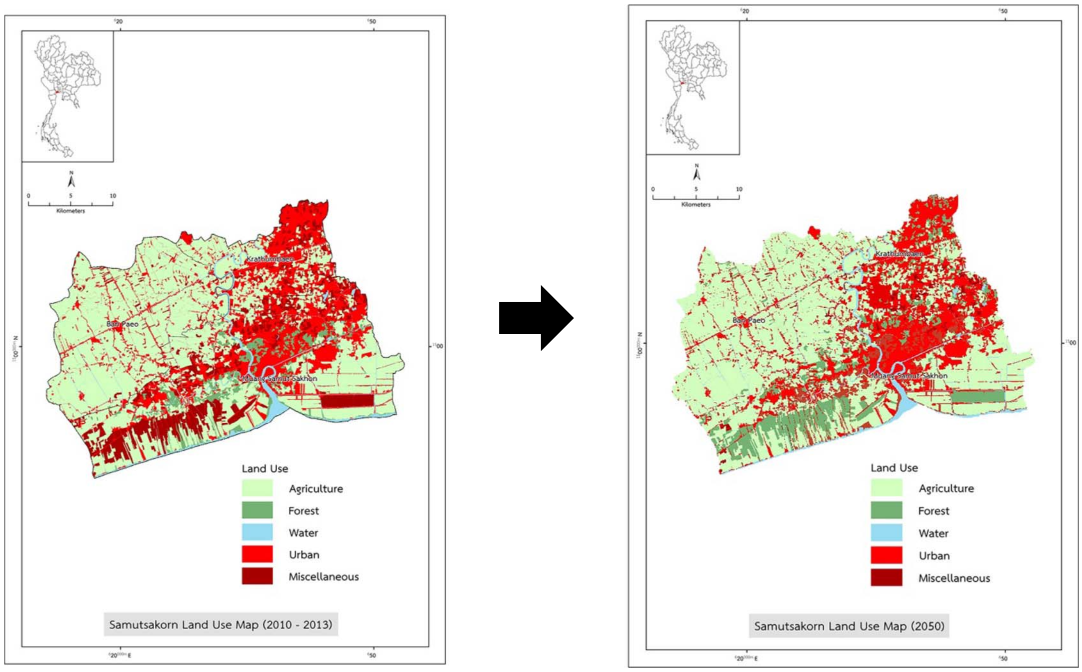

Fig. 5. A comparison between 2013 land use and 2050 modeled land use under SD scenario.

Table 2
Simplified matrix for ecosystem services of mangrove forest in 2050 comparing to 1960–1990.

	Sea level rise	Temperature	Precipitation	(BAU)	(SD)
Provisioning	–	x	x	–	+
Regulating	–	x	x	–	+
Habitat	–	x	x	–	+

implementation of land use policy which attempts to protect and to increase mangrove cover. Increase adaptive capacity of stakeholders would be fruitful in term of gaining relevant knowledge and practice to make coastal communities more resilience.

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